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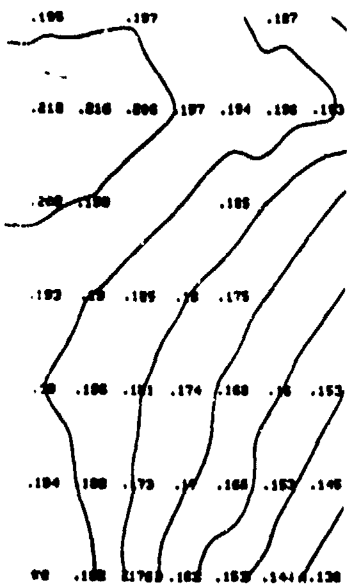

AUTOMATIC DATA PROCESSING CENTER

AD-A135 861

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INSTRUCTION REPORT K-83-6

USER'S GUIDE: INTERACTIVE GRAPHICS COMPUTER PROGRAM FOR CONTOURING RANDOMLY SPACED DATA

by

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October 1983
Final Report

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report documents a computer program for contouring a set of non-gridded (X, Y, Z) data points on a storage tube graphics terminal such as the Tektronix 4014 in the time-sharing environment. The program performs the contouring as follows:

a. Determines the polygon (using the data points as vertices) which surrounds the data and forms the convex hull;

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20. ABSTRACT (Continued):

b. Constructs a triangular mesh, using the data points as nodes, that falls inside the convex hull;

c. Contours inside each triangle using one of three methods: (1) linear interpolation, (2) spline under tension, and (3) bivariant polynomial.

This report also compares the results of this contouring program with an earlier version which uses a rectangular mesh concept. Some sample problems are also given.

PREFACE

This user's guide documents an interactive graphics program that can be used to contour randomly spaced data. The work in developing the program and writing this report was done as part of the engineering computer applications support provided by the Automatic Data Processing (ADP) Center of the U. S. Army Engineer Waterways Experiment Station (WES) to the U. S. Army Engineer Division, Lower Mississippi Valley (LMVD).

The contouring program is a modification of a program written by the Langley Research Center, National Aeronautics and Space Administration (NASA), and reported in NASA Technical Memorandum NASA TMX-72749. The work on the program described herein involved making the NASA program applicable to general type problems and modifying it to operate in the interactive mode with graphics terminals. Mr. Fred T. Tracy, Chief, Research and Development Software (RADS) Group, ADP Center, was responsible for this work and wrote the report. Mr. Kenneth Trahan, summer student, RADS Group, converted the program to execute on the WES computer.

Mr. James A. Young, Geology, Soils, and Materials Branch, was the LMVD point of contact. Dr. N. Radhakrishnan, Special Technical Assistant, ADP Center, and Mr. Paul K. Senter, Computer Aided Design Group, ADP Center, were project coordinators.

COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE, were Commanders and Directors of WES during development of the program modifications and preparation and publication of this report. Mr. F. R. Brown was Technical Director.

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CONTENTS

USER'S GUIDE: INTERACTIVE GRAPHICS COMPUTER PROGRAM FOR CONTOURING RANDOMLY SPACED DATA

PART I: INTRODUCTION

1. Contouring is a very useful and widely applied means of displaying engineering and scientific data in the Corps of Engineers. Types of data range from river bottom data to piezometer readings in an earth dam. For example, given (X, Y, Z) data points and the contour intervals, construct a contour map (Figure 1).

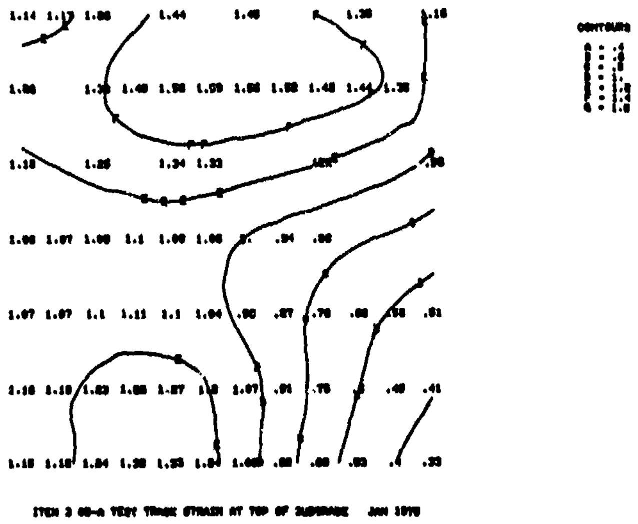

Figure 1. Contour plot

Background

2. In 1970, a general-purpose contouring program was developed.* Later in 1974, this program was adapted especially to output of the finite element method (FEM).** While each of these made significant contributions to the U. S. Army Engineer Waterways Experiment Station (WES) capability, problems

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* J. T. Long and F. T. Tracy. 1970. "A General Purpose Contouring System," Miscellaneous Paper T-70-1, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

** F. T. Tracy. 1974. "A Computer Program for Contouring the Output of Finite Element Programs," Miscellaneous Paper K-74-1, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

still existed. First, the algorithms used were slow, making the programs unsuitable for use on the new time-sharing graphics terminals. Second, the contour map was sometimes incorrect. This is illustrated by the small data set shown in Figure 2. Note that the data represent a perfectly symmetric hill

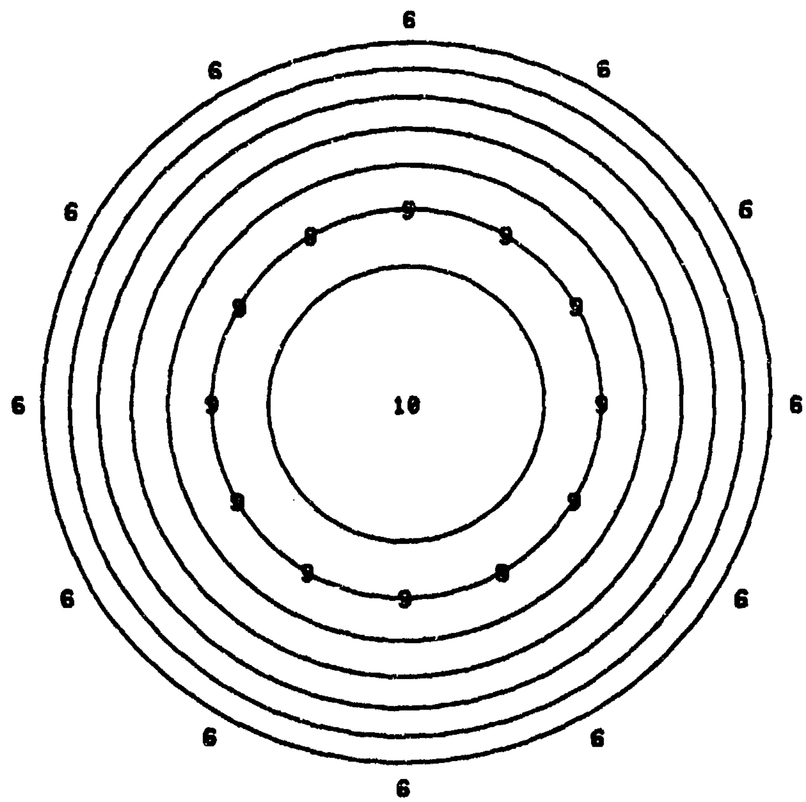

Figure 2. Small data set

10 ft* above sea level at its crest and 6 ft above sea level at its base. Note also that the contour levels of 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, and 9.5 are circles whose center is at the 10-ft data point. Figure 3 shows the computer-generated contour map from the 1974 program. The erroneous lines at the four extremities can at least be removed by adding four new (X, Y, Z) points at the extremities (see the 5-ft data points in Figure 4). However, this plot is also unacceptable.

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* Multiply feet by 0.3048 to convert to meters.

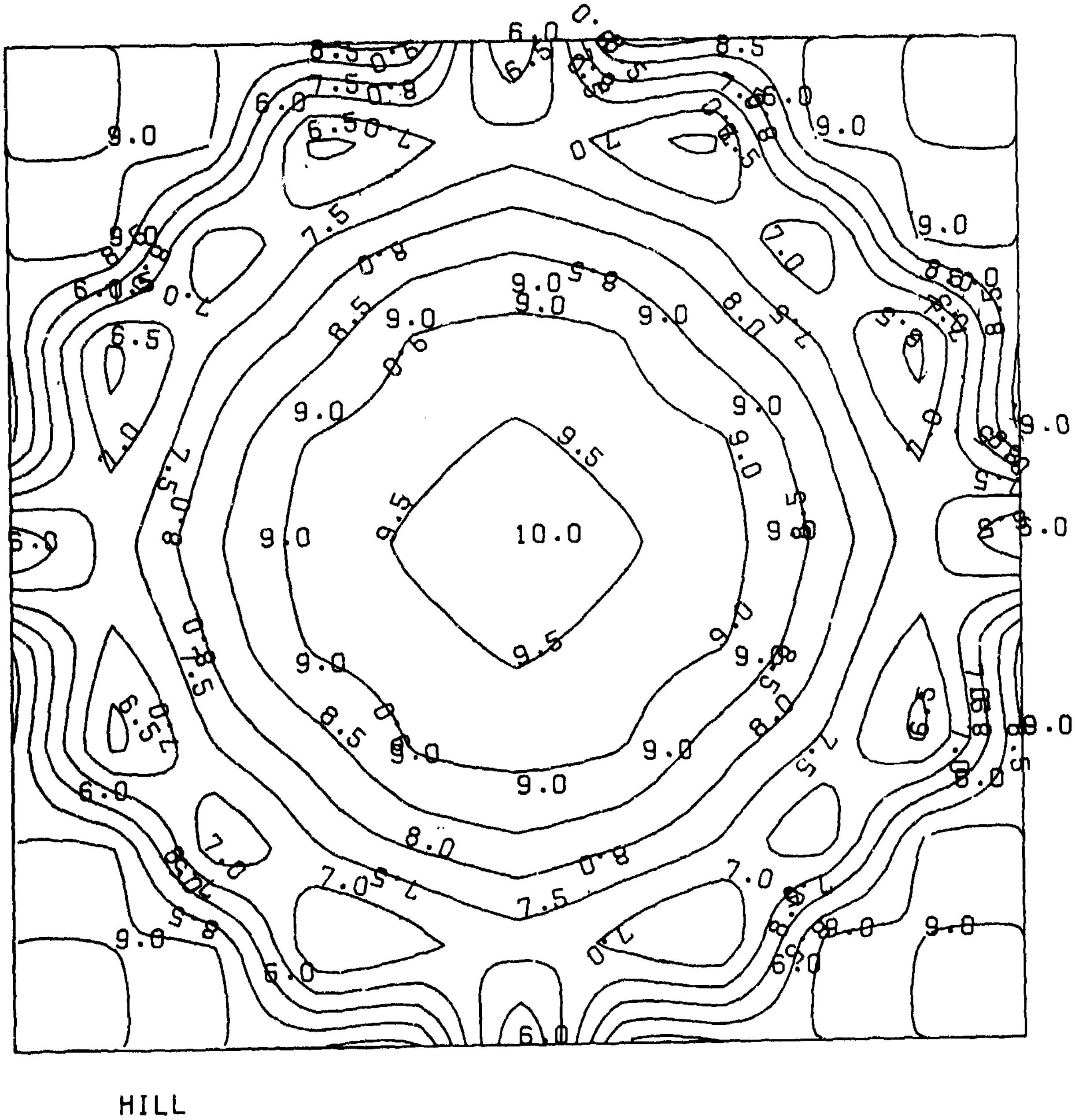

Figure 3. 1974 program result

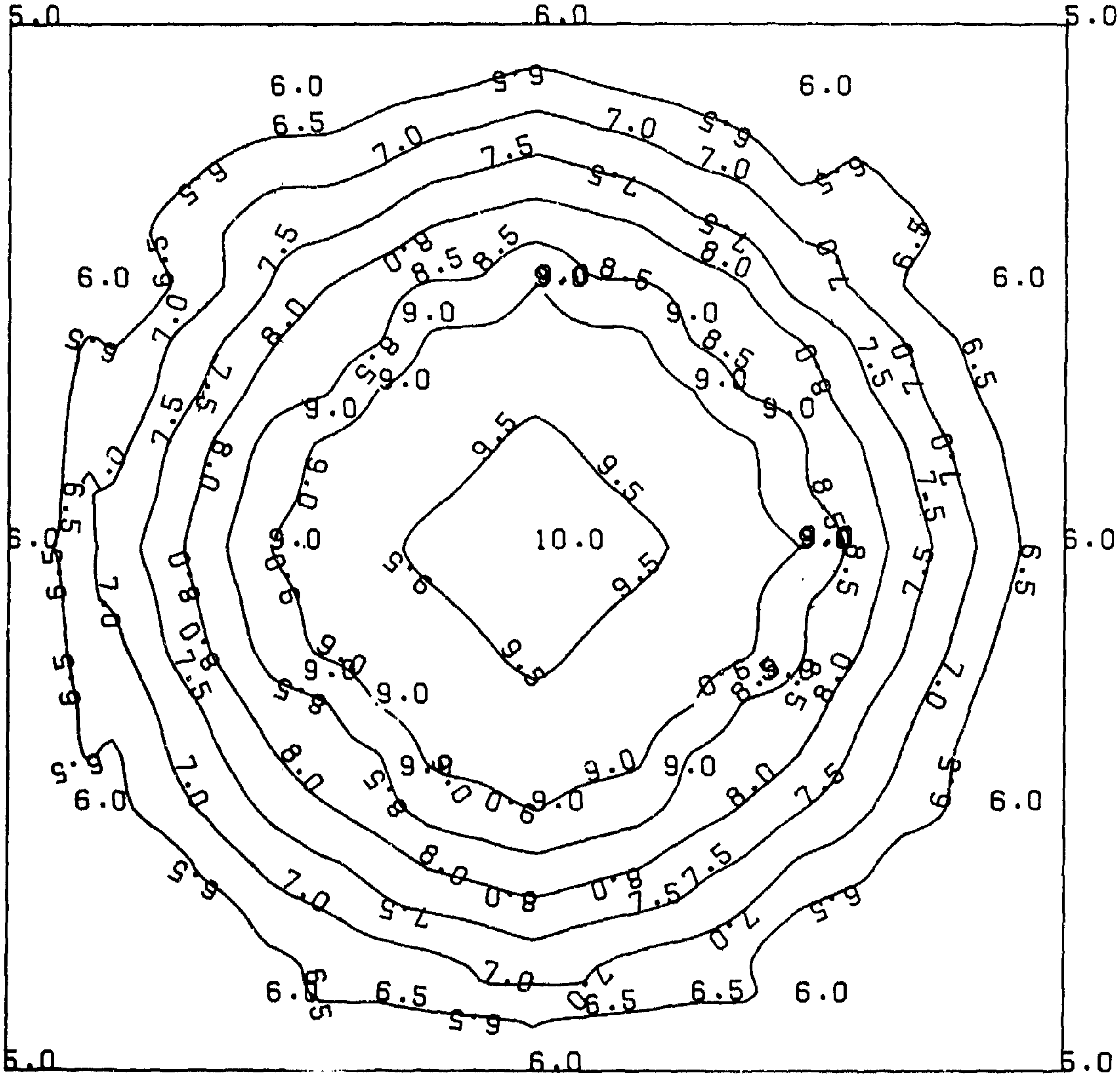

Figure 4. Result with points added

Technique of 1970 and 1974 Programs

3. These programs work by:

   a. Forming a rectangular grid around the data points (Figure 5).

   b. Computing Z values at all grid points from given (X, Y, Z) data points.

   c. Contouring inside each rectangle.

4. The problems resulting from this technique are:

   a. The grid does not match the data points.

   b. Z values at all the grid points are costly to compute.

   c. Z values computed at the grid points are sometimes incorrect.

What is clearly needed is a new approach to the problem.

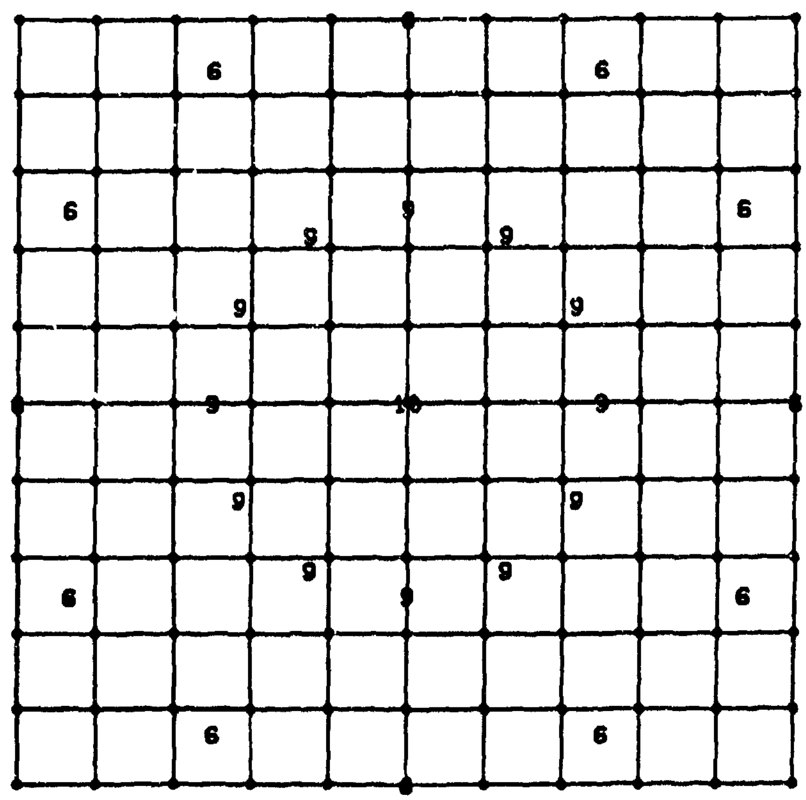

Figure 5. Rectangular grid

New Program

5. The goal is to develop a program that has:

   a. Short execution time.

   b. Time-sharing or batch capability.

   c. Simple input.

   d. Accurate contours.

This goal has been achieved by adapting state-of-the-art techniques to these specific needs.

Procedure

6. The small data set (Figure 2) can now be used to describe the procedure of the new contouring program as follows:

   a. Define the convex hull (Figure 6). This is the smallest convex polygon that encloses the (X, Y, Z) data points.

   b. Create a triangular grid with each of the (X, Y, Z) data points becoming a node (see Figure 7).

   c. Contour inside each triangle.

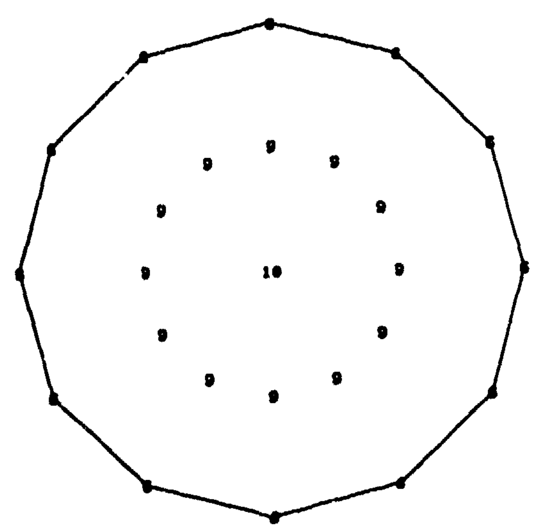

Figure 6. Convex hull

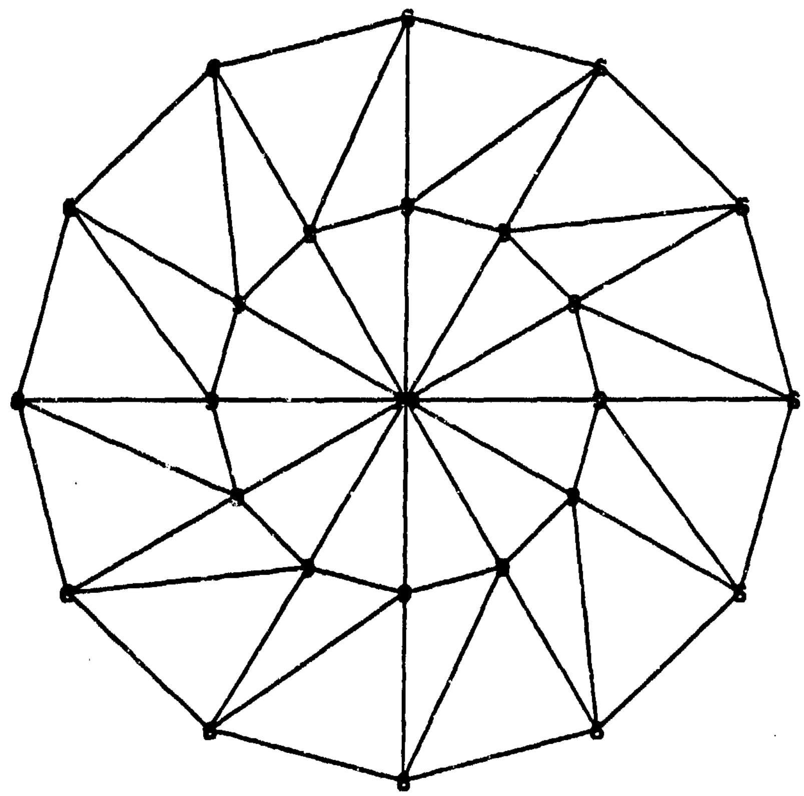

Figure 7. Triangular grid

7. These are three interpolation techniques used for determining the contour lines inside the triangles.

a. Linear interpolation (Figure 8).

b. Spline under tension (Figure 9).

c. Fifth-order bivariant polynomial (Figure 10).*

8. By providing a range of sophistication in interpolation techniques, the user can select the one best suited to his needs. Figures 11-13 show a practical example with the three interpolation procedures applied to it.

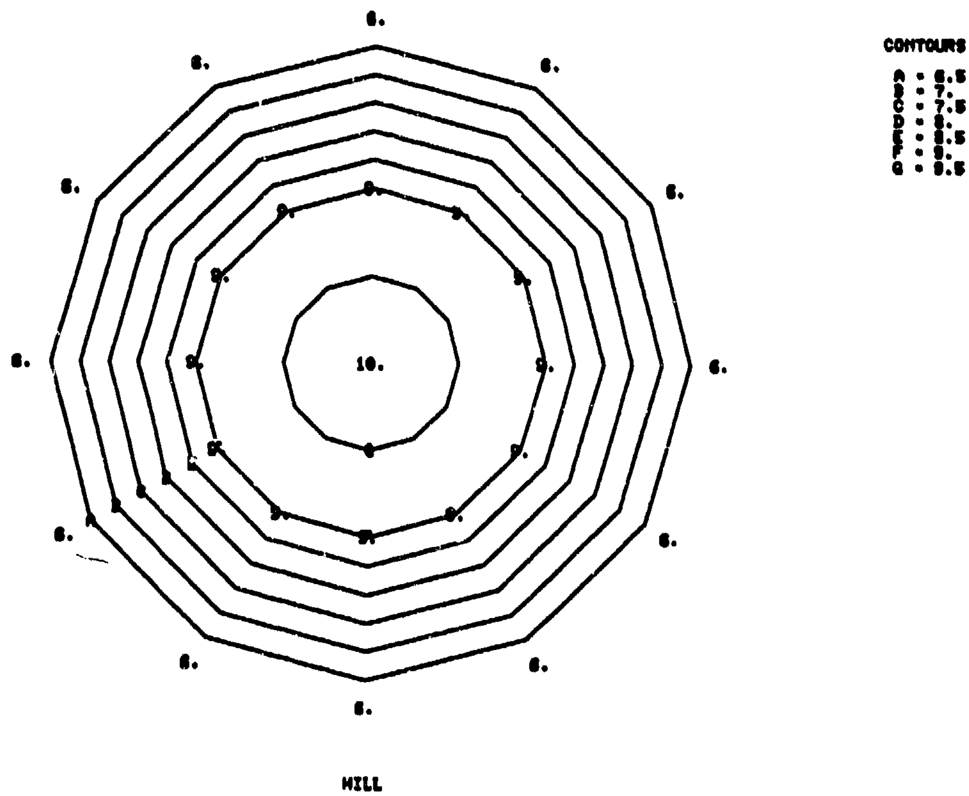

Figure 8. Linear interpolation

* Hiroshi Akima. 1975. "A Method of Bivariant Interpolation and Smooth Surface Fitting for Values Given at Irregularly Distributed Points," OT Report 75-70, Institute for Telecommunication Sciences, Department of Commerce, Boulder, Colo. 80302.

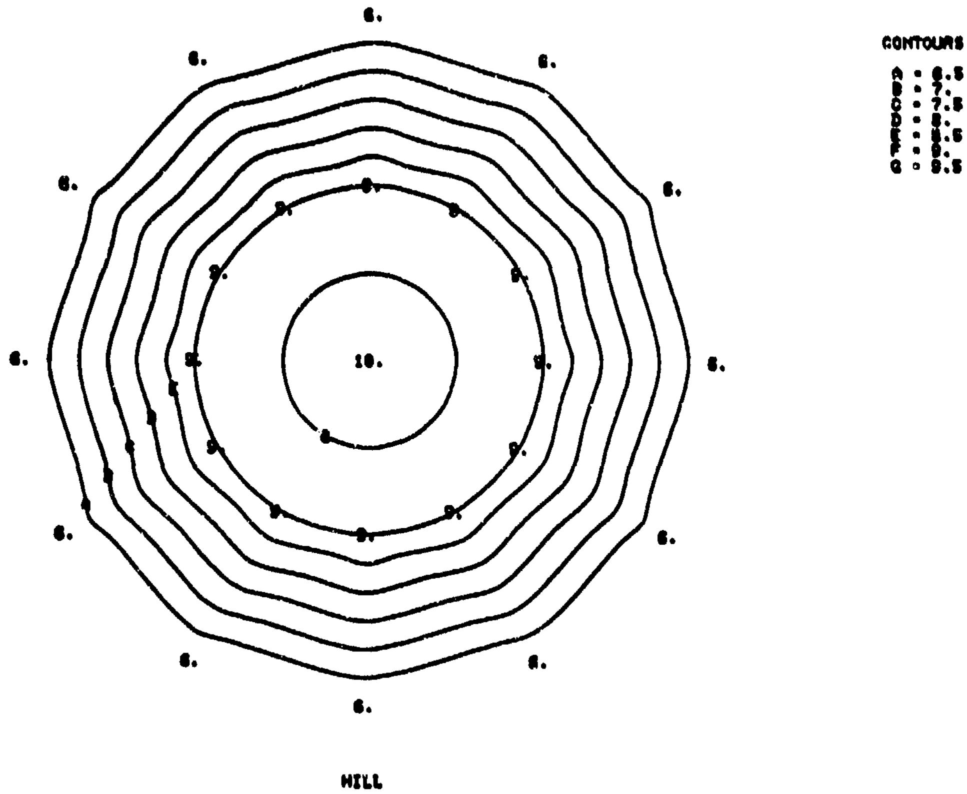

Figure 9. Spline under tension

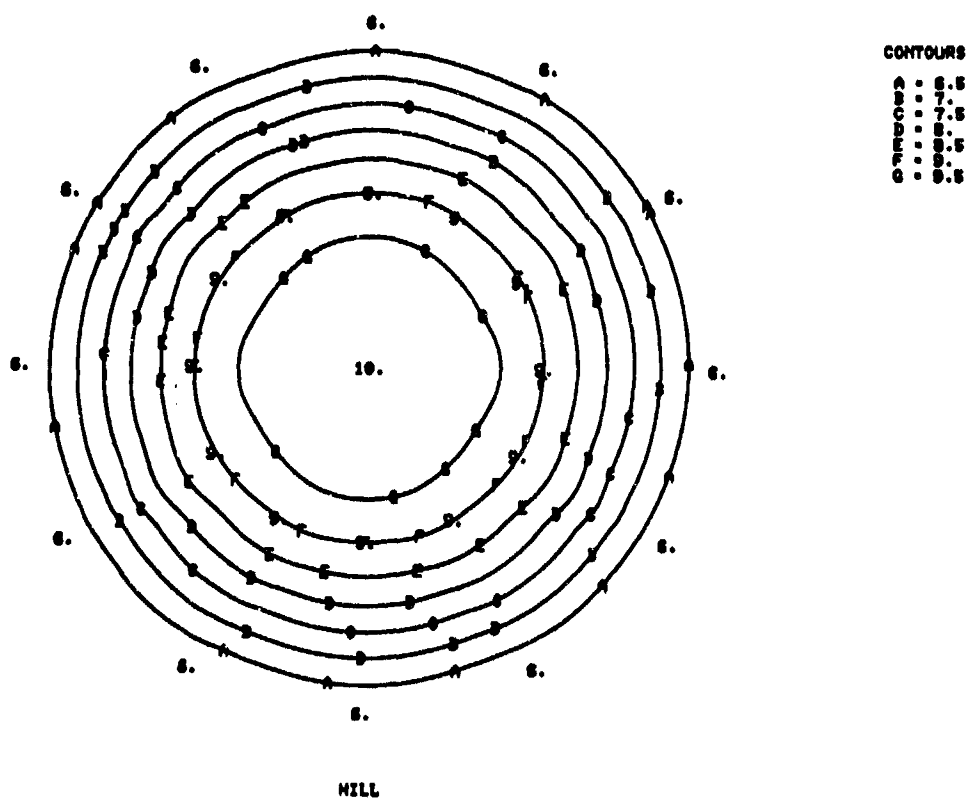

Figure 10. Fifth-order bivariant polynomial

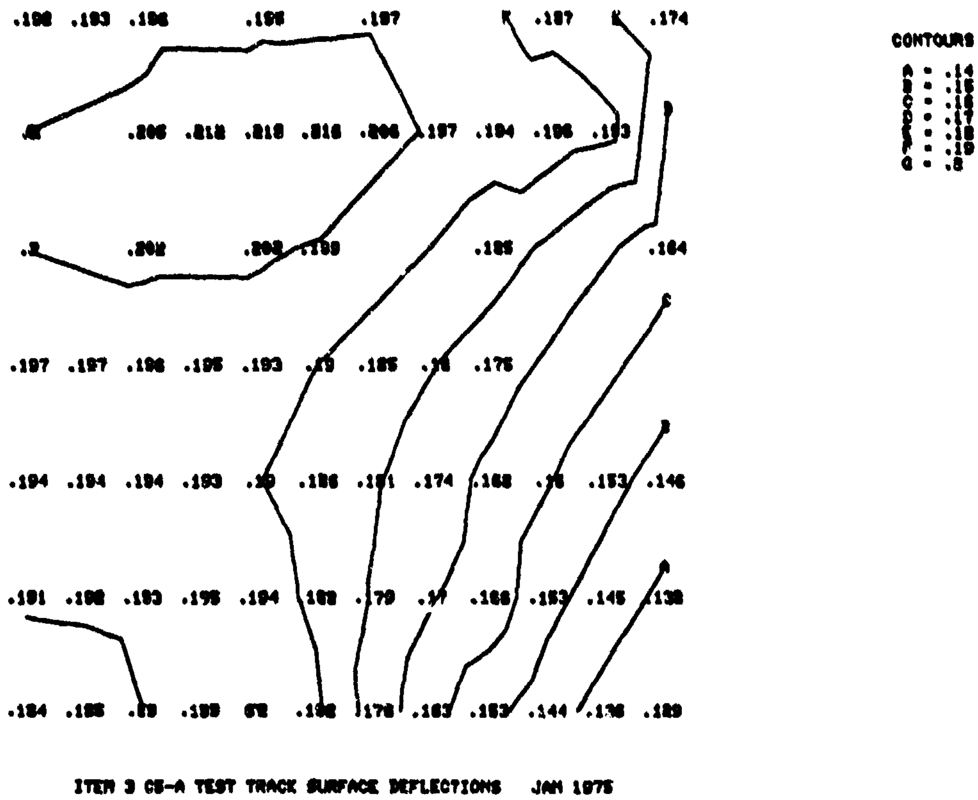

Figure 11. Practical example - linear interpolation

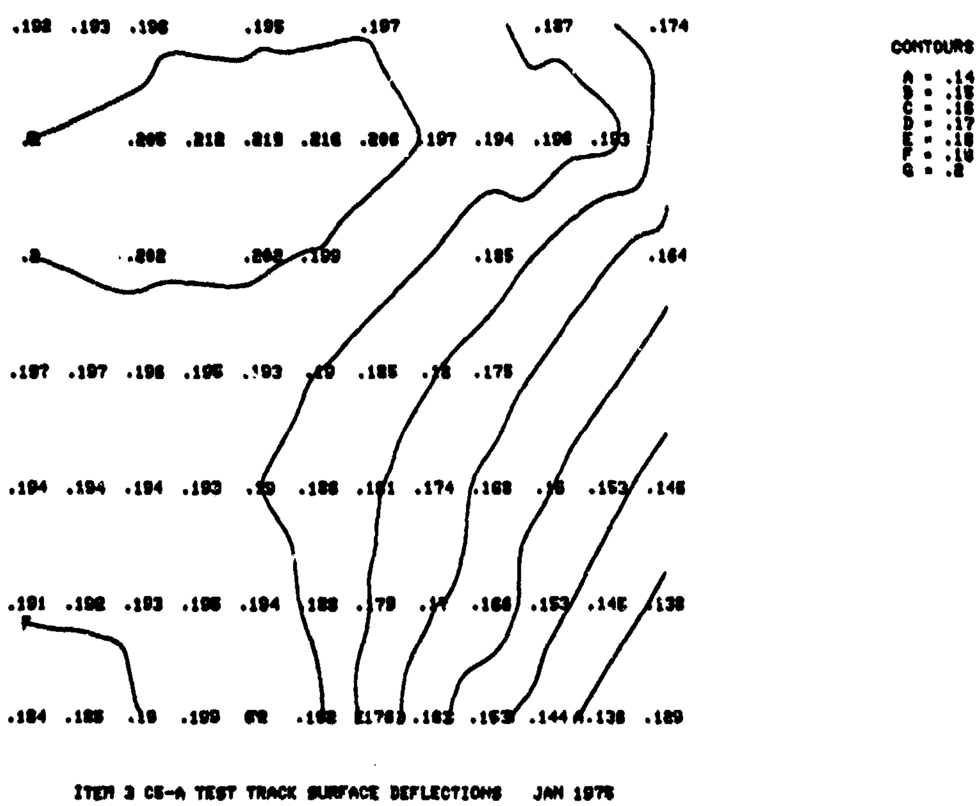

Figure 12. Practical example - spline interpolation

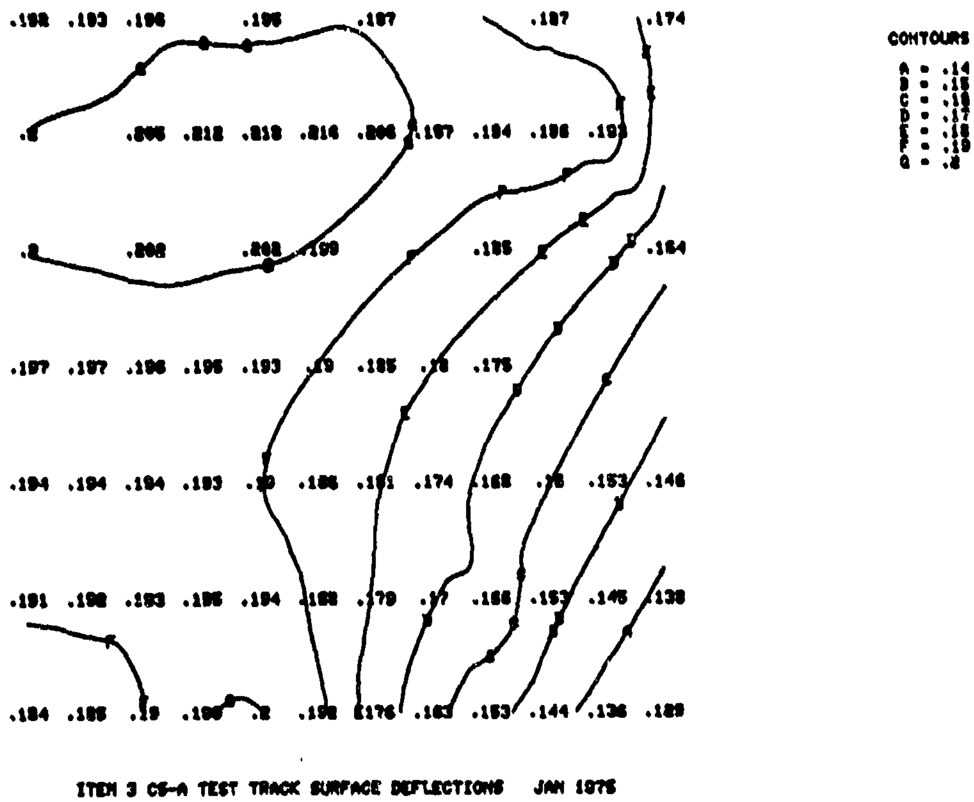

Figure 13. Practical example - polynomial interpolation

Advantages

9. The new technique offers several advantages:

   a. Grid points match data points. Thus, no costly computation of Z values at grid points is needed. This also assures correct Z values at the grid points.

   b. Convex hull eliminates contouring where there is no data.

   c. Accurate contours.

10. The user's guide for the program is presented in Part II.

PART II: USER'S GUIDE

Computer Program Requirements

11. This program is written in FORTRAN IV for the Honeywell time-sharing system. Plots are obtained on a graphics terminal such as the Tektronix 4014 or an off-line device such as a Calcomp drum plotter.

CORPS Library Number

12. This program, number U0003, is in the Conversationally Oriented Real-Time Program Generating System (CORPS) Library.

Description of Input Data

Data file

13. A data file is first prepared containing:

a. A title card.

b. (X, Y, Z) data points.

The data file is a line-numbered file and is read in free-field format. At least one space must separate the line numbers from the data, and the data are separated by a comma or at least one space. The first line of the data file contains a title (not to exceed 72 characters), and each succeeding line of data must contain an (X, Y, Z) data point. The listing to the left is the data file for the plots in Figures 8-10. Note that the (X, Y, Z) data points can be given in any order and do not have to be counted. A maximum of 500 data points (300 for polynomial interpolation) can be handled in this time-sharing version of the program. The data are to be saved in a file whose name starts with a letter and has no more than eight characters.

```
*OLD HILL
*LIST

10 HILL
20 0 0 10
30 5 0 9
40 4.33 2.5 9
50 2.5 4.33 9
60 0 5 9
70 -2.5 4.33 9
80 -4.33 2.5 9
90 -5 0 9
100 -4.33 -2.5 9
110 -2.5 -4.33 9
120 0 -5 9
130 2.5 -4.33 9
140 4.33 -2.5 9
150 10 0 6
160 8.66 5. 6
170 5. 8.66 6
180 0 10 6
190 -5. 8.66 6
200 -8.66 5. 6
210 -10 0 6
220 -8.66 -5. 6
230 -5. -8.66 6
240 0 -10 6
250 5. -8.66 6
260 8.66 -5. 6
```

Interactive mode

14. The user is now ready to run or execute the contouring program. The first question asked is

LINEAR, SPLINE, OR POLYNOMIAL?

Here the user responds with one of the three interpolation types. Only the first character (L, S, or P) is required, but any number of letters can be supplied.

15. The next question is

INPUT DATA FILE NAME?

This corresponds to the name of the data file that contains the title and (X, Y, Z) data points. A one- to eight-character name is allowed, with the first character being alphabetic.

16. The next question is

NUMBER OF CONTOUR LEVELS, 1ST LEVEL, LAST LEVEL?

The contour levels are computed by dividing the difference between the first level and the last level equally so as to obtain the requested number of contour levels. Any number of these sets of data can be input by typing a set after each

MORE?

question. However, the total number of contour levels cannot exceed 50. To go to the next question, type a carriage return.

17. The next question asked is

PLOT NUMBERS?

This option allows the user to plot the input data points (Z values) centered at their respective (X, Y) positions on the contour plot. The user can then check the accuracy of the generated contour lines. If "Y" or "YES" is the answer, the question

NUMBER OF PLACES TO RIGHT OF DECIMAL POINT?

is asked. This allows plotting of the Z values at the proper accuracy.

18. The next question asked is

DO YOU WANT A DRUM PLOT?

If "N" or "NO" is given, the contour plot is then drawn. If "Y" or "YES" is the answer, the following additional question and answer sequence is followed to spawn the batch job to create the magnetic tape used to produce the drum plot.

```
ENTER HEIGHT OR PLOT IN INCHES (POSITIVE NUMBER)
OR SCALE FACTOR IN UNITS/INCH  (NEGATIVE NUMBER)
= SOME NUMBER
ENTER IDENT CARD INFORMATION
FOR WES:  USERID,NAME
= USERID, NAME
INPUT STATION CODE FOR OUTPUT (00 IF NOT REMOTE)
= 00
WANT DEFAULT SETTINGS (YES-OR-NO)
(PLAIN PAPER, PEN 1-BLACK BALL POINT,
  PEN 2-RED BALL POINT, PEN 3-GREEN BALL POINT,
  PEN 4-BLUE BALL POINT, REGULAR PEN SIZE)
= YES
INPUT PRIORITY (5 OR 40)
= 5
SNUMB = 1234E
```

19. After the contour plot is drawn, the bell will ring and the program will pause. The user can then make a hard copy before typing a carriage return to go back to the "NUMBER OF CONTOUR LEVELS, 1ST CONTOUR LEVEL, LAST CONTOUR LEVEL?" question. The user can type a carriage return and advance backward one question to "INPUT DATA FILE NAME?" In fact, the program is designed to allow the user to advance to the previously asked question at any time by hitting a carriage return (except for the "MORE?" question).

Sample Problem

20. The sample problem given below demonstrates use of the program. The data file appears as follows:

```
*OLD C5AOCT
*LIST

10 TEST 3 C5-A TEST TRACK OCT SHEAR AT TOP OF SUBGRADE  JAN 1975
20     0.        0.        2.57
30     6.00      0.        2.65
40    12.00      0.        2.81
50    18.00      0.        3.00
60    '24.00     0.        3.04
70    60.00      0.        0.82
80    54.00      0.        1.12
90    48.00      0.        1.49
100   42.00      0.        1.95
110   36.00      0.        2.43
120   66.00      0.        0.66
130   30.00      0.        2.83
140    0.       12.90      2.57
150    6.00     12.00      2.62
160   12.00     12.00      2.74
170   18.00     12.00      2.88
180   24.00     12.00      2.88
190   30.00     12.00      2.71
200   36.00     12.00      2.39
210   42.00     12.00      1.99
220   48.00     12.00      1.61
230   54.00     12.00      1.27
240   60.00     12.00      1.00
250   66.00     12.00      0.84
260    0.       24.00      2.32
270    6.00     24.00      2.35
280   12.00     24.00      2.42
290   18.00     24.00      2.47
300   24.00     24.00      2.44
310   30.00     24.00      2.31
320   36.00     24.00      2.12
330   42.00     24.00      1.88
340   48.00     24.00      1.63

350   54.00     24.00      1.39
360   60.00     24.00      1.21
370   66.00     24.00      1.04
380    0.       36.00      2.29
390    6.00     36.00      2.32
400   12.00     36.00      2.37
410   18.00     36.00      2.42
420   24.00     36.00      2.41
430   30.00     36.00      2.33
440   36.00     36.00      2.18
450   42.00     36.00      2.05
460   48.00     36.00      1.92
470    0.       48.00      2.61
480   12.00     48.00      2.79
490   24.00     48.00      3.00
500   30.00     48.00      2.98
510   48.00     48.00      2.70
520   66.00     48.00      2.17
530    0.       60.00      2.89
540   12.00     60.00      3.16
550   18.00     60.00      3.42
560   24.00     60.00      3.59
570   30.00     60.00      3.66
580   36.00     60.00      3.59
590   42.00     60.00      3.51
600   48.00     60.00      3.42
610   54.00     60.00      3.33
620   60.00     60.00      3.15
630    0.       72.00      2.63
640    6.00     72.00      2.69
650   12.00     72.00      2.89
660   24.00     72.00      3.31
670   36.00     72.00      3.34
680   54.00     72.00      3.13
690   66.00     72.00      2.69
```

Interactive session

21. First, a linear plot is obtained without plotting the Z values as follows:

```
*RUN WESLIB/CORPS/U0003,R
LINEAR, SPLINE, OR POLYNOMIAL?
=L
INPUT DATA FILE NAME?
=C5AOCT
NUMBER OF CONTOUR LEVELS, 1ST LEVEL, LAST LEVEL?
=6 .5 3
MORE?
=
PLOT NUMBERS?
=N
DO YOU WANT A DRUM PLOT?
=N
```

Figure 14 shows the resulting plot.

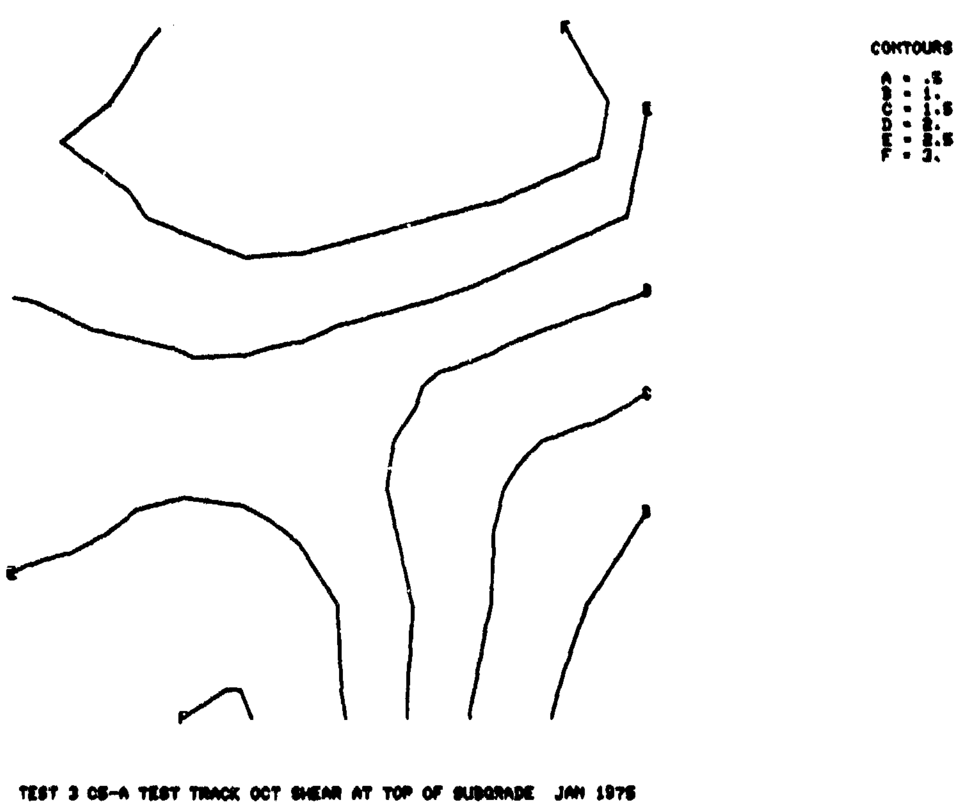

Figure 14. Linear plot without numbers

22. Next, a contour map can be generated using the polynomial interpolation scheme and plotting the input Z values with accuracy of two places to the right of the decimal point. After a carriage return is typed, the following question and answer sequence is followed:

```
NUMBER OF CONTOUR LEVELS, 1ST LEVEL, LAST LEVEL?
=
INPUT DATA FILE NAME?
=
LINEAR, SPLINE, OR POLYNOMIAL?
=P
INPUT DATA FILE NAME?
=C5AOCT
NUMBER OF CONTOUR LEVELS, 1ST LEVEL, LAST LEVEL?
=6 .5 3
MORE?
=
PLOT NUMBERS?
=Y
NUMBER OF PLACES TO RIGHT OF DECIMAL POINT?
=2
DO YOU WANT A DRUM PLOT?
=N
```

Figure 15 shows the resulting plot.

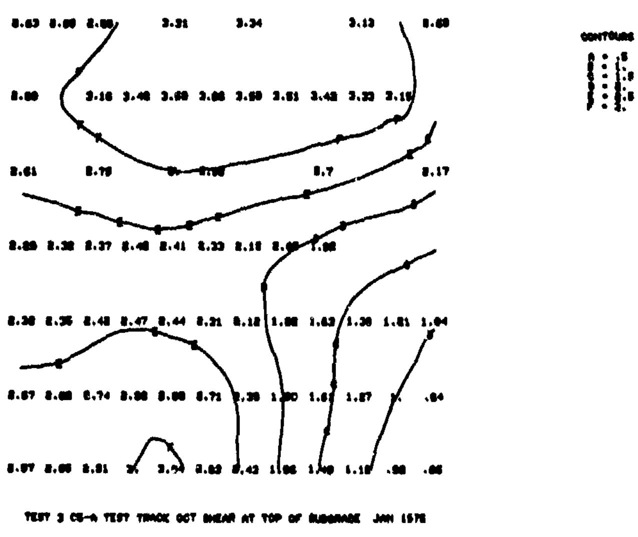

Figure 15. Polynomial plot with numbers